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PROGRAM MANAGEMENT COURSE
INDIVIDUAL STUDY PROGRAM

REVIEW OF AIR FORCE AND NAVY SPARE AIRCRAFT ENGINE REQUIREMENTS METHODOLOGY

STUDY PROJECT REPORT
PMC 76-1

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DEFENSE SYSTEMS MANAGEMENT SCHOOL

STUDY TITLE: Review of Air Force/Navy Spare Aircraft Engine Requirements Methodology

STUDY PROJECT GOALS:

1. Review of Air Force and Navy spare aircraft engine requirements methodology for conformance to DOD policy.
2. Enhance the researcher's knowledge of Navy policies.
3. Determine if there is a perceived need to re-convene the DOD Sub Task Group on Spare Aircraft Engine Requirements.

STUDY REPORT ABSTRACT:

The purpose of this study was to review the acquisition and management of spare aircraft engines in the Air Force and the Navy. The researcher reviewed for conformance of the requirements methodology in DODI 4230.4 and compared the Air Force and Navy organization and management structures pertaining to aircraft engines. Additionally, spare engine/module requirements for modularly designed engines are addressed.

Key Words: Spare Engines, Requirements, Acquisition
MOD-METRIC, NAVMET

KEY WORDS ALSO

MATERIEL — REQUIREMENTS
MATERIEL — MAINTENANCE
SPARE PARTS
REQUIREMENTS
AIRCRAFT
AIRCRAFT MAINTENANCE
AIRCRAFT ENGINES
ORGANIZATION ANALYSIS

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REVIEW OF AIR FORCE AND NAVY SPARE AIRCRAFT ENGINE REQUIREMENTS METHODOLOGY

Study Project Report

Individual Study Program

Defense Systems Management School

Program Management Course

Class 76-1

by

Thomas Russell Harruff
GS-13 DAFC

May 1976

Study Project Advisor
CDR David P. Kirchner, USN

This study project report represents the views, conclusions and recommendations of the author and does not necessarily reflect the official opinion of the Defense Systems Management School or the Department of Defense.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The acquisition and management of aircraft engines is significant because of the large investment that is installed and spare engines:

Air Force	$ 6.8B
Navy	3.3B
Total	$10.1B

Because of the large dollar investment in engines the Department of Defense published (1971) an Instruction for use by all three services in developing spare engine procurement requirements. The General Accounting Office has initialed "a research effort to gather data on the methods used by the military services to determine aircraft engine requirements." Therefore, this project included a review of the methods used by the Air Force and the Navy to compute spare aircraft engine procurement requirements.

It was determined that both the Air Force and the Navy have implemented the DODI for computation of spare aircraft engine requirements for non-modularly designed engines. Further, each has developed a new requirements technique, based on RAND's Multi-Echelon Technique for Recoverable Item Control (METRIC), that considers the services' maintenance environment and the modular engine support scenario.

Differences were perceived between the Air Force and the Navy management of aircraft engines. These differences were explored and conclusions were drawn as to the reasons for these differences and their possible impact.

ACKNOWLEDGEMENTS

To CDR Dave Kirchner, my Study Project Advisor, I express grateful appreciation for support and the degree of freedom for my research.

Special appreciation must go to the personnel of the Naval Air Systems Command and the Naval Weapons Engineering Support Activity listed below for support, data, and interest in my project;

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Dr. James Matthesen

Jack Cook

Joseph Barlow

Robert Grider

SECTION I

INTRODUCTION

Purpose of the Study Project

The acquisition and management of aircraft engines has been recognized within the Department of Defense as a separate but unique part of the requirements process. Support of this statement is contained in Department of Defense Instruction 4230.4 dated 20 July 1971, Standard Method for Computation of Spare Aircraft Engine Procurement Requirements.

The purpose of this study is to review, compare, and contrast the management of spare aircraft engines within the Departments of the Air Force and Navy. Additionally, I will focus on the spare engine requirements methodologies in both the Air Force and Navy.

Specific Goals of the Project

The goals of this study are threefold:

a. In January 1975 the General Accounting Office (GAO) notified the Assistant Secretary of Defense (Comptroller) that they were "initiating a research effort to gather data on methods used by the military services to determine aircraft engine requirements." (7:1) Therefore, the first goal of this project is to review Air Force and Navy policy, procedures, and requirements methodology for conformance to established DOD policy and procedures.

This notation will be used through the report for sources of quotations and and major references. The first number is the source listed in the bibliography. The second number is the page in the reference.

b. The second goal of this study is to enhance the researcher's knowledge of the Navy's policy, procedures, and methodology for possible application, where appropriate, to Air Force propulsion system acquisition and management strategies.

c. One final goal is to determine if there is a perceived need within the Air Force and Navy to recommend to OSD that the DOD Sub-Task Group on Spare Engine Requirements be re-convened to review and update DODI 4230.4.

Scope of Project

While limited in scope to one unique part of the DOD requirements process, this study project involves large inventories and dollar expenditures within both the Air Force and Navy. Figures 1 through 4 provide insight into the size of Air Force and Navy inventories of engines and the respective size of their proposed annual spare engine procurement programs:

Inventory Size

Air Force (as of 31 Dec 75)

	Quantity	Dollars (In Millions)
Jet Engines		
Installed	28,877	$ 4,780
Spare	9,368	1,618
	38,245	$ 6,398
Reciprocating		
Installed	2,669	$ 86
Spare	2,836	131
	5,505	$ 217
Missiles		
Installed	212	59
Spare	216	24
	428	$ 83
Small Gas Turbines		
Installed	6,927	$ 106
Spare	2,257	36
	9,184	$ 142
Total Engines		
Installed	38,685	$ 5,031
Spare	14,677	1,809
GRAND TOTALS	53,362	$ 6,840

FIGURE 1

Source: AFLC, Requirements Inventory Analysis Report (RIAR), RCS: LOGS-188, 1 Jan 76

Inventory Size

Navy (as of 31 Dec 75)

	Quantity	Dollars (In Millions)
Jet Engines		
Installed	10,663	$ 2,328
Spare	3,839	787
	14,502	$ 3,115
Reciprocating		
Installed	2,507	$ 128
Spare	1,125	58
	3,632	$ 186
Total Engines		
Installed	13,170	2,456
Spare	4,964	845
GRAND TOTALS	18,134	$ 3,301

FIGURE 2

Source: NAV AIRSYSCOM, AIR-4122, Mr. Joseph Barlow

NOTE: The Navy does not manage missile or small gas turbine engines in their Engine Status Accounting System. These engines are managed within other Navy inventory systems.

Annual Spare Engine Procurements

Air Force (as of 1 Jan 76) (Dollars in Millions)

Aircraft/Engine	FY 75	FY 76	FY 7T	FY 77
A-10/TF34GE100	$ 9.6	$ 3.9	$ .040	$ 17.7
E-3A/TF33PW100	2.7	.5	0	6.1
F5E/J85-21	4.3			
F-15/F100PW100	108.0	104.8	23.5	62.1
TOTAL	$124.6	$109.2	$23.54	$ 85.9

FIGURE 3

Source: AIR Force BP1600 Aircraft Initial Spares, FY 77 President's Budget, 1 Jan 76

Annual Spare Engine Procurements

Navy (as of 1 Jan 76) (Dollars in Millions)

Aircraft/Engine	FY 75	FY 76	FY 7T	FY 77
A-7/TF41A2	$ 7.5	$ 3.0	$ 1.5	$ 3.2
A-4M/J52P408		2.7	.9	3.8
A-6E/J52P8B		2.1		1.5
F-14/TF30P412	26.8	16.5	4.0	5.8
CH53/T64GE415				1.7
AH-1T/T400WV402				1.3
P-3C/T56A14		2.1	.5	1.3
E-2C/T56A425	1.5	2.1	.5	.8
S-3A/F34GE400	7.9	21.8		2.4
UH-IN/T400CP400		1.9		
TOTAL	$ 43.7	$ 52.2	$ 7.4	$ 21.8

FIGURE 4

Source: NAV AIRSYSCOM, AIR-4122, Mr. Joseph Barlow

Limitations of the Report

I have limited my research to the Air Force and Navy because of my knowledge of Air Force policy and procedures and the relative availability of Naval Air Systems Command in the immediate area. Extension of this study to the Army would require a visit to the Aviation Systems Command in St Louis. The limiting of this study to the Air Force and Navy was initially based on preliminary research on all three services propulsion system management systems. A large similarity exists between the acquisition and management of propulsion systems within the Air Force and the Navy; therefore I have concentrated my research in the comparison of their techniques.

Additionally, I have limited my research to the acquisition and management of whole engines and modules. Time precludes extension of the formal report to include the repair of whole engines and/or the acquisition and repair of engine spare parts. Although it is recognized that management philosophy and policy should encompass all three requirements areas in order to more efficiently and effectively utilize available scarce dollar resources.

An additional limitation is that the study will be confined to the acquisition and management of large turbine engines. This will include jet, turbofan, and turboprop engines used as the prime propulsion system on Air Force and Navy aircraft systems. Excluded from the study are reciprocating engines, liquid and air breathing rocket engines, and small gas turbine engines used as auxiliary power units.

Organization of the Report

The balance of this report is organized into three sections. The present situation in the Air Force and Navy will be covered in Sections II and III. My observations, conclusions, and proposed follow-on actions are included in Section IV.

SECTION II

AIR FORCE SECTION

Air Force Management Philosophy

Within the Air Force propulsion systems have been managed under a separate philosophy since the 1950s. That philosophy - selective management - is similar to the concept of management by exception. This policy "provides for more precise control of costly items and with decreased control of low cost items." (6:7)

The Air Force has constantly updated and upgraded its logistics systems to meet the challenge of higher cost, more sophisticated, from both an acquisition and operational support cost viewpoint, weapons systems. The Air Force "objective has been to develop a responsive logistics support structure that will support modern weapons economically and maintain both readiness during peace and combat effectiveness during war." (6:7)

The large Air Force dollar investment in propulsion systems ($6.8B) and the high acquisition cost of new engines (approaching $2 M each for the F100PW100) causes the Air Force to continue to apply the policy of selective management to propulsion systems. AFM 400-1 states:

> "The philosophy of selective management is constant. It is not subject to change, although the procedures are always subject to periodic change. It is always important to incorporate improvement that take advantage of each technological advance in equipment and each refinement in management control." (6:7)

This management philosophy has resulted in the development of a separate Air Force logistics system for propulsion systems. This system is supported by a major data system - the Propulsion Unit Logistics System. This system shall be identified hereafter by its Data System Designator - D024.

The central theme of Air Force propulsion system management philosophy and of the D024 is serialized control of all Air Force propulsion units from an inventory gain until the engine is transferred out of the Air Force or sent to disposal. The Air Force currently manages over 53,000 propulsion units with an acquisition value of $6.8B within the D024. The Air Force Logistics Command has been delegated the responsibility for the development, implementation, and maintenance of a centralized management and accounting system for all Air Forced owned propulsion units. This function is accomplished under a centralized computer controlled inventory account at Oklahoma City Air Logistics Center, Tinker AFB, Oklahoma.

AFLC receives input data daily of all changes in the world wide location, status, or condition of all Air Force propulsion units. These daily changes are reported by serial number and are the basis for updating one or more of the major sub-systems in the D024. These sub-systems and their titles are as follows: (6:41)

D024 A Propulsion Unit Data Collection Status Sub-System

D024 B Propulsion Unit Inventory Management Sub-System

D024 C Propulsion Unit Allocation and Distribution Sub-System

D024 D Propulsion Unit Pipeline Analysis Sub-System

D024 F Propulsion Unit Actuarial Experience Computation Sub-System

D024 I Propulsion Unit Engine Configuration Management Sub-System

D024 J Propulsion Unit Actuarial Forecast Computations Sub-System

D024 K Propulsion Unit Financial Inventory Accounting Sub-System

D024 L Propulsion Unit Base Level Reporting Sub-Systems
(AFLC Peculiar)

Through the design, implementation, and use of the D024, with its various sub-systems, the Air Force provides a separate logistics system for the selective management of propulsion units from gain to loss. Included in this central data system is all data concerning sequential flows of engines through the various phase of the Air Force's engine management system. The flow of engines within the Air Force is depicted below and is based upon a bi-level system (intermediate and depot) of off-wing engine maintenance.

Simplified Engine Flow Diagram

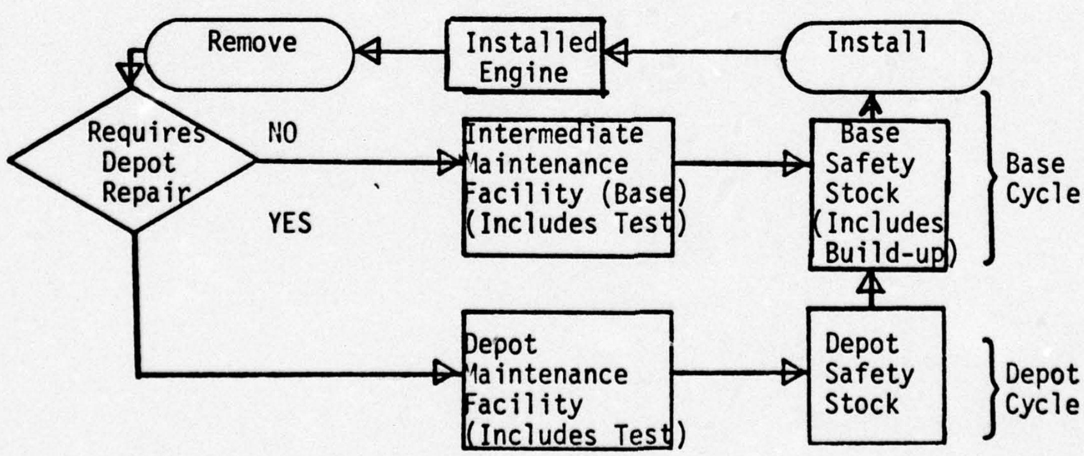


FIGURE 5

The above engine flow cycle is the heart of both management and requirements for spare engines. One can readily see that in a dynamic environment engines are either in a state of semi rest in one of the blocks of the diagram or in transit between blocks of the diagram. The rate of flow through the base and depot portions of the flow diagram is a function of engine operating hours and failures or removals per some segment of operating hours.

Both of these points - serialized control and the concept of a dynamic flow of engines - are the basis for the Air Force management system. Serialized reporting enables the Air Force to maintain positive control of all assets; track failure rates and patterns; and record the length of time an engine remains in each segment of the flow cycle. Management's job, then, is to design a reliable engine that can be maintained economically and timely at the lowest maintenance level; assure that transportaion time between bases and depots is strictly controlled; and develop an operational and maintenance environment that provides a desired level of operational support with a minimum of resources (in this case spare engines).

Another advantage of the Air Force management system is the concept of automatic re-supply. Within the Air Force all base level engine transactions (change reports) are prepared/controlled by an individual (civilian or military) that has been designated as the Base Engine Manager. Upon determination that an engine requires depot level repair/maintenance the Base Engine Manager submits a change of status report

to the D024. This status report automatically updates the inventory record and the computer determines if a servicable engine must be shipped to replace the one that requires shipment to depot for repair. This decision is based upon comparison of the number of engines on hand and due in with the base's authorized level. If re-supply action is necessary the computer sends a notice to the Engine Inventory Manager (EIM) to institute automatic re-supply action. No formal re-quisitioning system exists; therefore distribution of engines within the Air Force is based on a change in engine condition rather than a physical movement or requisitioning process. This type of a distri-bution system is called a push rather than a pull system.

To summarize, the Air Force uses a selective management philosophy for propulsion systems due to their high dollar value for acquisition, operation, and support. This selective management philosophy has been implemented through the application of a computerized, centralized, serialized accounting and control system. The Air Force management philosophy and system are designed to provide maximum readiness with a minimum investment in spare aircraft engines.

Organization

Engine management in the Air Force has been centralized within the Air Force Logistics Command (AFLC). This major command headquarters is responsible for developing policy and procedures for Air Force wide management of propulsion systems. They are responsible for preparing the basic Air Force policy document for engine management - AFM 400-1.

This manual, after review by the HQ USAF, is applicable to all commands in the Air Force.

AFLC has also been delegated the responsibility to chair two Air Force wide committees that are the major governing bodies in the Air Force that impact engine management. The two committees and their functions are as follows:

a. Air Force Engine Logistics Planning Board (ELPB) - "The function of this board is to establish policy and provide guidance on matters relative to the management of propulsion systems." (6:10) Membership on the board will consist of a senior representative (appointed by the DCS/Logistics) from each major operational command. Representatives from HQ USAF will act in an advisory capacity.

b. Aerospace Engine Life Committee (AEL) - The functions of this committee are to establish various forecast factors relating to engine management as a result of their review of actuarial, statistical, and technical information. Membership to the AEL is similar to the ELPB except that the major command representatives usually have a maintenance background and are of a lower grade level than the ELPB members. (6:15)

As stated earlier in this paper a further example of the centralization of engine management within AFLC is the fact that they developed, control, and operate the Air Force's Propulsion Unit Logistics System (D024).

A further horizontal and vertical centralization of engine management in the Air Force occurs through the establishment of a Command Engine Manager in every major command headquarters and the establishment of a Base Engine Manager at every Air Force base. These positions, their functions and duties, are established by AFM 400-1 and they

provide a vertical engine management chain within a command and a horizontal chain between commands. It is possible to find military and civilian personnel in the Air Force who have been involved in engine maintenance and/or management for most of their careers. This organizational structure provides for a stable environment for Air Force engine management.

A continuing of the centralization of Air Force engine management occurs within the Air Force Logistics Command. AFLC has elected to retain the responsibility for spare engine procurement requirements computation at the headquarters level while the balance of the engine management functions have been delegated to San Antonio and Oklahoma City Air Logistics Centers (ALCs). These two ALCs have been delegated the responsibility for management and repair of whole engines and engine spare parts. Figure 6 provides a graphical presentation of these relationships:

HQ USAF	Approve and publish policy in AFM 400-1 and act as advisors to ELPB and AEL.
HQ AFLC	Develop engine management policy, compute spare engine requirements, and Chair ELPB and AEL.
Air Logistics Centers	Manage whole engines and engine spare parts. Determine procurement and repair requirements for engine spare parts and repair requirements for whole engines and engine spare parts.

FIGURE 6

To summarize, the Air Force has elected to provide strong centralized control of their $6.8B inventory of installed and spare engines. The basis for this centralized control and management is AFLC's Propulsion Unit Logistics System (D024). This centralized engine serialized control and reporting system enables the Air Force to provide cost effective weapon system support while miminizing their investment in spare assets.

Requirements Methodology

DOD policy and procedures for the computation of spare engine procurement requirements are covered in DODI 4230.4 dated 20 July 1971. This procedure is an adaptation of the spare engine requirements methodology used by the Air Force prior to issuance of the DODI. The Air Force utilizes the standard spare engine requirements methodology and DOD forms for all non-modularly designed engines.

In order to better understand the spare engine requirements computation methodology, it is necessary to become familiar with many of the terms used by the services. While this list is not complete, it will provide a base for a common language and understanding of the Air Force/DOD spare engine requirements computated:

Actuarial Removal Interval (ARI) A factor developed for use in forecasting engine removals. It is a ratio of operating hours to engine removals.

Overhaul Removal Interval (OHRI) An ARI factor developed for use in forecasting removals for major overhaul.

Base Maintenance Removal Interval (BMRI) An ARI factor developed for use in forecasting engine removals for base maintenance. (Intermediate Repair)

Combined Maintenance Removal Interval (CMRI) An ARI factor developed for use in forecasting total engine removals (removals for major overhaul and for base maintenance).

Automatic Resupply and Build Up Time (ARBUT) The time from base submission of an engine status change stating an engine has been removed for major overhaul until the base receives a servicable engine and builds it up for installation into an aircraft.

The computation methodology used by the Air Force is directly related to its maintanance levels. The Air Force basically uses a two echelon maintenance system (see Figure 5). The first level is the base repair cycle for maintenance work authorized at base level - periodic inspections, base level TCTO and intermediate repair. The second level is the depot overhaul cycle for maintenance requiring depot level facilities and skills - major overhaul. These two maintenance levels and the pipeline time required to supply the base with a replacement engine for one removed for depot level overhaul comprise the major segments of the requirements computation. A safety level factor is added at base and depot level to provide for fluctuations in forecast number of engine removals and in the demand at depot or elsewhere in the engine pipeline.

With these segments in mind, we will now look at the base for a spare engine computation. This base is the aircraft flying hour program contained in the applicable Hqs. USAF generated program documents. These include:

USAF Program - Aerospace Vehicles and Flying Hours (PA)

USAF War Mobilization Plan, Volume 6 (WMP-6)

USAF Military Assistance Program; Part II; Aircraft, Missiles, and Flying Hours (PA-M)

USAF Aircraft Production Schedule (WA) (6:66)

From the above documents are selected or computed the number of squadrons or bases, number of active aircraft, and aircraft and engine operating hours for a 30 day period. Both wartime and peacetime flying hours are extracted and the greater of the two is used for the computational base to assure that support is available for the greater of the two flying hour programs. The 30 day engine operating hours are divided by the Overhaul Removal Interval (OHR) to compute the expected number of major overhaul removals for that period. A daily number of removals is also calculated and then multiplied by the number of days in the Automatic Resupply and Build-up (AR BUT) pipeline to compute that segment. Division of the 30 day engine hours by the Base Maintenance Removal Interval (BMRI) provides the expected number of base maintenance removals for that period. Again, a daily rate is calculated and multiplied by the number of days in the base maintenance cycle to compute that segment. The total of the ARBUT and Base Maintenance quantities is divided by the number of squadrons or bases to give an average per squadron or base. This figure is used in computing the base 90% confidence level safety factor to assure that sufficient assets are on hand to meet requirements that fluctuate above the average. Multiplication of the ARBUT, Base Maintenance, and Safety Level Quantities by the number of squadrons or bases provides a command level requirement. After the above, the depot segments are computed. These are just the daily

depot overhaul removal rate times the number of days in the depot overhaul cycle plus a depot safety level requirement based on a 90% confidence factor. A sample computation follows to show the mechanics of the Air Force methodology. An outline explanation is provided for the entry on each line of the sample computation:

SPARE ENGINE

REQUIREMENTS COMPUTATION

EXAMPLE	FLYING HOURS Peace	FLYING HOURS War
1. No of Sqdns or Bases (from Program Document)	5	5
2. No of O/A Aircraft (from Program Document)	90	90
3. Aircraft Flying Hours (from Program Document)	6750	9000
4. Engine Operating Hours (#Engines x Acft Flying Hours)		18000
5. OHRI (from ARI Table)		900
6. Removals - Overhaul - 30 days (line 4 ÷ line 5)		20.000
7. Removals - Overhaul - Daily (line 6 ÷ 30 days)		.667
8. ARBUT days (from AFM 400-1)		15
9. ARBUT Requirement (line 7 x line 8)		10.005
10. BMRI (from ARI Table)		300
11. Removals - Base Maint - 30 Days (4÷10)		60.000
12. Removals - Base Maint - Daily (11 ÷ 30 days)		2.000
13. Base Maint - Pipeline Days (from AFM 400-1)		18
14. Base Maint Requirement (12 x 13)		36.000
15. ARBUT and Base Maint Req - Command (9 + 14)		46.005

SPARE ENGINE

REQUIREMENTS COMPUTATION

EXAMPLE	FLYING HOURS	
	Peace	War
16. ARBUT and Base Maint Req - Sqdn/Base (15 ÷ 1)		9.201
17. ARBUT, Base Maint and Safety Req (from AFM400-1)		13
18. Total Command Req (1 x 17)		65
19. Depot Overhaul Cycle Days (from AFM 400-1)		34
20. Depot Overhaul Cycle Req (7 x 19)		23
21. Depot Safety Level Req (7 x 21)		6
22. Total Requirement (18 + 20 + 21)		94

FIGURE 7

In summary, the Air Force spare engine requirements computation is based upon a variety of factors that determine the number of engines needed to fill the various segments of the pipeline.

Program Documents - These classified documents are furnished to the Air Force Logistics Command from Hqs USAF and provide the flying hours, number of aircraft, and number of squadrons or bases used in the requirements computation.

Actuarial Removal Intervals - The Overhaul Removal Interval (OHRI) and Base Maintenance Removal Interval (BMRI) are, in the initial phases of an aircraft/engine buy program, milestones or estimates.

These factors usually double or triple as actual experience is gained through extended engine use and short lived components are redesigned and improved through the Component Improvement Program (CIP).

Base Maintenance Flow Times - A standard based upon past experience on an engine of similar complexity. Again, early extended flow times usually use up the depot safety level assets.

Automatic Resupply and Build-up Time (ARBUT) - This standard is based upon the past average number of days to ship a spare engine and build it up for installation. (This segment is called Engine Requisition and Build-up-time (ERBUT) by the Navy.)

These factors are a combination of scientific methodologies (ARI Tables and Base Safety Level Tables) and standards based upon past performance of similar engines that may or may not be justifiable estimates. The Air Force/DOD methodology provides a fairly straightforward, fully visible presentation of the requirements process for non-modularly designed engines.

Spare Engine and Module Requirements

At the time that the current DODI 4230.4 was drafted (1970-71) it was recognized that some of the new generation engines would be designed for quick disassembly into maintenance modules and that this design concept would reduce the number of whole engines in the maintenance pipelines. These engines will be replaced by quantities of the lower indenture modules flowing through the base and depot maintenance pipelines. Recognizing that the DOD methodology did not mathematically

treat either the interaction of a two-echelon (base and depot) or a two-indenture (whole engines and modules) inventory problem, the services were told to adapt the existing methodology for spare engines and modules.

The Air Force went a step further and adapted the RAND developed Multi Echelon Technique for Recoverable Item Control (METRIC) for computing requirements for spare engines and modules. A discussion of the Air Force's adaptation (Modified METRIC or MOD-METRIC) of this technique is beyond the scope of this paper but can be found on pages 472-481 in the December 1973 issue of Management Science or in AFLCP 57-13, Recoverable Inventory Control Using MOD-METRIC dated 28 February 1975.

A graphical representation of a two-echelon, two-indenture inventory model for modularly designed engines is included as Figure 8.

Perusal of the two-echelon, two-indenture inventory model reveals that the objective of the modularly designed engine is to shorten the time for repair of whole engines. This is accomplished by fault isolation to a defective module; removal and replacement by a servicable module; and returning the engine to a servicable status. If this is accomplished at the lowest echelon base level, the repair time for whole engine is reduced and the number of days an engine is servicable is substantially increased. The failed module is then repaired at either base or depot level depending on the extent or type of failure. Replacing a high cost engine in the maintenance pipelines with a mix of lower cost modules results in a cost effective trade off that provides

TWO-ECHELON, TWO-INDENTURE MODEL

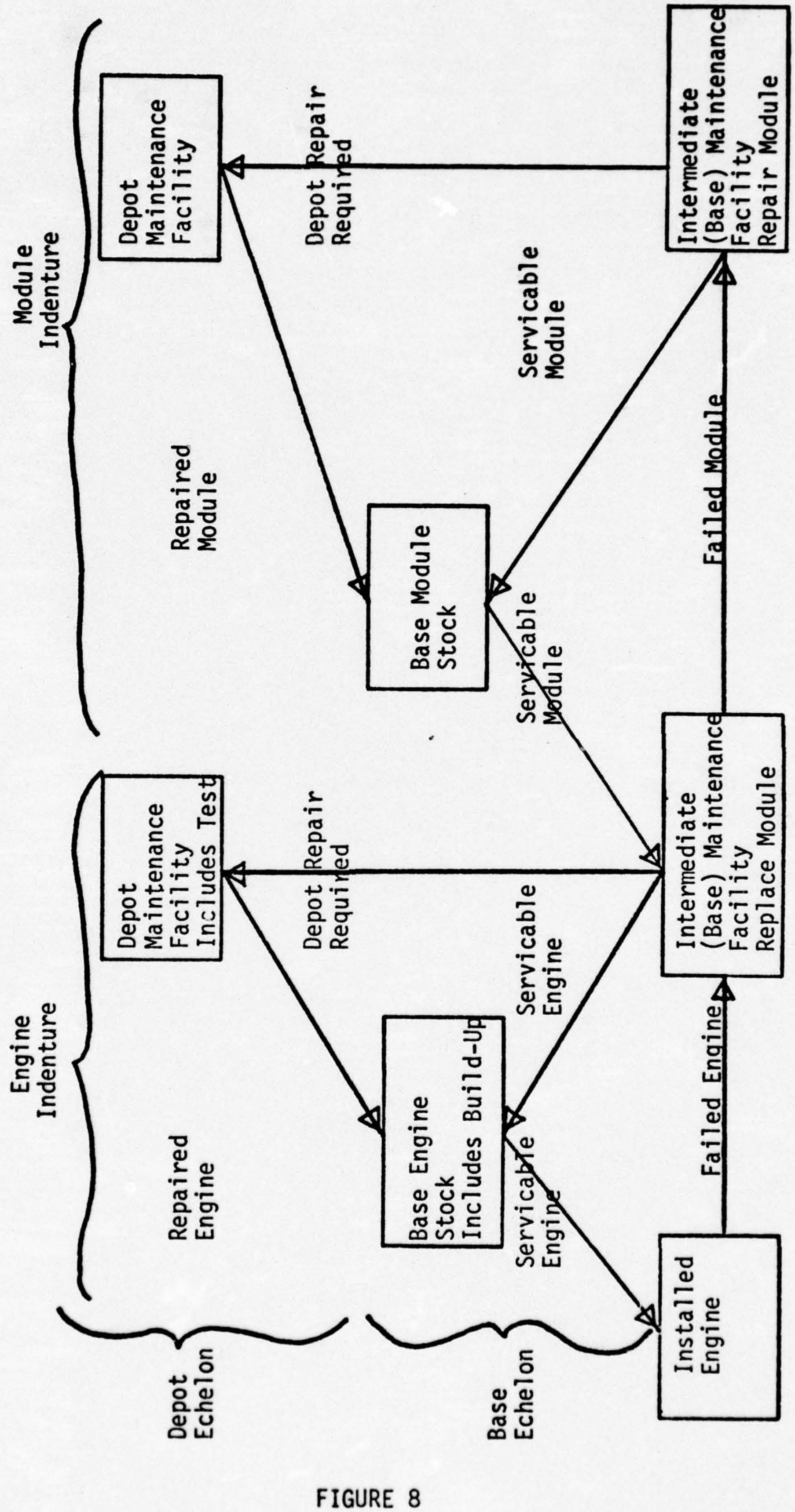


FIGURE 8

the same level of engine availability at a lower investment in spare engines and spare modules.

This requirements technique was first implemented in the Air Force in 1971 for spare engines and spare modules to support the F-15 aircraft. It was briefed through the Air Staff to OSD/I&L(SR) and accepted for Air Force application to modularly designed engines. AFLC has continually refined the model and is just now revising the model to compute

Although MOD-METRIC requires the same elements of data on the engine and each module, it provides a better allocation of requirements between engines and modules. It trades off some whole engines for a mix of modules and for the F-15 developed requirements, when compared to the DODI 4230.4 methodology, provides the same forecast level of support for a savings of $44 M.

In summary, the Air Force currently uses two separate requirements techniques. The first - for non-modularly designed engines - is in accordance with DODI 4230.4. The second - for modularly designed engines - has been approved by OSD but has not been officially covered in a DOD instruction for use by all three services.

SECTION III

NAVY SECTION

Navy Management Philosophy

The date for this section of the paper are based upon personal interviews with Naval Air Systems Command and Naval Weapons Engineering Support Activity personnel and review of various Navy studies and policy documents. I will provide a comparison with the Air Force baseline established in Section II.

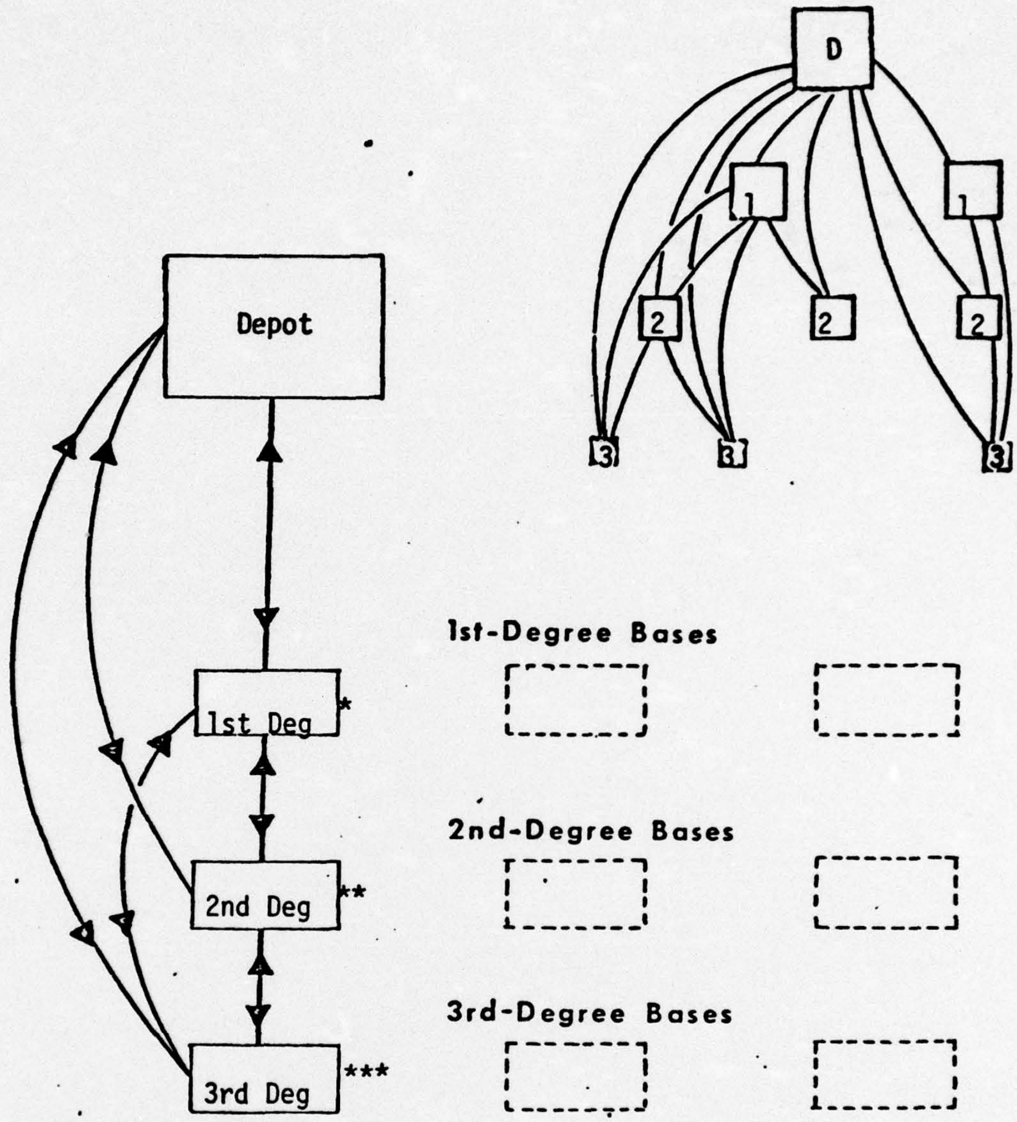
The Navy has also recognized that aircraft engines are a significant portion of their total inventory ($3.3 B) and have therefore developed a unique, serialized engine inventory/status accounting system that parallels the Air Force's Propulsion Unit Logistics System. However, the Navy system does not match the Air Force system in either breadth or depth of coverage. The Navy's Aircraft Engine Accounting System (EAS) does not contain missile or small gas turbine (auxillary) engines. These types of engines are managed within other Navy inventory systems. In a similar fashion, the Navy EAS does not contain some of the various subsystems of the Air Force's D024 system. Configuration control and actuarial data are two primary areas that are treated separately from the EAS. There is, however, an interface between the EAS and the Navy's new actuarial system. This new actuarial system - Statistical Calculation and Analysis for the Logistics of Engine Removals (SCALER) Methodology was developed by the Naval Weapons Engineering Support Agency for the Naval Air Systems Command.

The basis for the Navy's Engine Status Accounting System is a daily exception reporting, by serial number, of changes in condition, location or status of their engines. These reports, similar to the Air Force, are sent via Autodin or electrically transmitted by a message. While the Air Force uses the D024 for daily management between AFLC and the Major Commands (MAJCOMS), the Navy does not appear to have a strong centralized control. This difference could be the result of the Navy's decentralization of engine management; their Type Commands (TYCOMS) need for independent operation within their sphere of influence; or their four-echelon maintenance system.

As I indicated earlier (Figure 5) the Air Force uses a rather simplified two-echelon (intermediate and depot) maintenance system. This enables the Air Force to maintain strict serial number control of assets in the maintenance pipelines and forecast the flow of engines through the pipeline. However, the Navy engine maintenance system is somewhat more complicated due to the four-echelon or level system shown in Figure 9.

Dr. Muckstadt describes the Navy four-echelon system structure in his paper on NAVMET as follows:

> "The four-echelon system consists of a group of bases and a depot. Each of the bases is capable of performing only certain types of maintenance. First-degree bases can perform almost all types of maintenance except engine overhauls. Second-degree bases have the capability to repair only a portion of the engine malfunctions that a first-degree base can repair. A third-degree base has only a very limited repair capacity and consequently performs only minor maintenance. The depot, on the other hand, can perform all types of repair. Malfunctions experienced at a base may be repaired at that base or may



* A 1st-degree base may serve zero, one, or more 2nd-degree bases, and all the 3rd-degree bases subordinate to those 2nd-degree bases.

** A 2nd-degree base may serve zero, one, or more 3rd-degree bases, but is itself subordinate to only one 1st-degree base.

*** A 3rd-degree base is subordinate to only one 2nd-degree and to only one 1st-degree base.

FIGURE 9

be sent to some higher echelon (lower degree numbered base or the depot) for repair. Depending on the type of malfunction that occurs, it is assumed that the location at which repair will take place is known.

Furthermore, it may be assumed that the supply and maintenance systems for an engine can be represented by the tree given in Figure 9. Specifically, it may be assumed that the set of bases can be partitioned into a collection of mutually exclusive and collectively exhaustive and collectively exhaustive sets. Each set is characterized by having exactly one first-degree type base in it and a collection of second- and third-degree type bases logistically subordinate to the first-degree base. This set is called a degree-one family. The subordinate second- and third-degree bases are assumed to receive all first-degree resupply from the first-degree base in that set. Similarly, to each subordinate second-degree base in the set there corresponds a set of third-degree bases that it resupplies. The set whose members are the second-degree base and the bases logistically supported by that second-degree base is called a degree-two family. No third-degree base is resupplied by more than one second-degree type base." (14:17)

This maintenance structure significantly increases the management problem (centralized management) because a failure at a third-degree base could be repaired at that level, or forwarded to any one or successively all of the levels or echelons above the third-degree base. Therefore, a third-degree failure could flow as follows:

Engine Flow Diagram

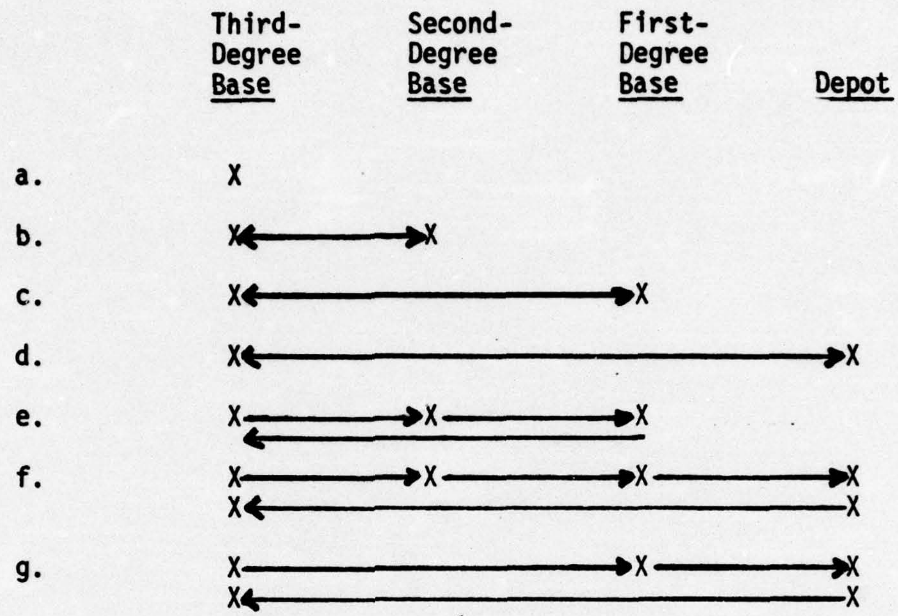


FIGURE 10

a. Third-degree failure repaired on site.

b. Third-degree failure forwarded to second-degree, repaired, and returned.

c. Third-degree failure forwarded to first-degree, repaired, and returned.

d. Third-degree failure forwarded to the depot, repaired, and returned.

e. Third-degree failure forwarded to second-degree and subsequently to first-degree, repaired and returned.

f. Third-degree failure forwarded to second-degree, then to first-degree, then to the depot, repaired, and returned.

g. Third-degree failure forwarded to first-degree and subsequently to depot, repaired, and returned.

There are seven combinations with a depot and single first-, second-, and third-degree base set up. These become increasingly more difficult to manage when there are different Navy TYCOMS and the Marine Corps involved in the mix of first-, second- and third-degree bases. Navy maintenance policy and planning personnel indicated that some TYCOMS will ship an engine to a more distant second- or first-degree base because the near bases (first and second) are controlled by another TYCOM or the Marines.

Another problem that makes the centralization of Navy aircraft engine management difficult is that the criteria for determining if an engine should be repaired at a higher level and at which higher level are not uniformly applied throughout the Navy. Therefore, management and control of engines in the Navy has been more decentralized to the the TYCOMS.

The Navy has also established a multi-command engine management group. The Engine Life Management Group (ELMG) is chaired by Naval Air Systems Command with voting members from the five Navy Operating or Type Commands. OPNAV INST 13790.1 states that:

> In the past, management of aircraft engine programs (i.e., spare engine procurement, repair parts support, engine rework forecasts, etc.) has been accomplished throughout the Naval Establishment without optimum coordination. This has frequently resulted in program imbalance and an inefficient utilization of existing resources. Automatic data processing systems have provided the means of making actuarial data available to all commands in sufficient time to provide for a coordinated effort. It has been determined that establishment of an ELMG to review and approve engine management

factors for use by Operating/Logistics Forces is the most efficient way of insuring an effective engine management effort. Thus, all commands should plan future actions based upon joint decisions reached by the ELMG regarding the many factors involved in engine management." (18:1)

NAVAIR INST 13790.1 further states that:

> "The ELMG will furnish the basic centralization now missing in engine life management and afford all commands a voice in determining and approving the many factors involved in life management of an ever increasing financial inventory of Navy engines." (17:1)

The Navy took a step forward in further centralization of engine management when NAVAIRSYSCOM presented a new centralized computation of pool requirements for the various TYCOMS. Previously the TYCOMS had independently calculated the spare engine requirements and submitted them to NAVAIR to be satisfied. Wide variations existed between the commands in methodology and stability of total Navy requirements for budgeting and planning was difficult to achieve. Under the new procedure NAVAIR, based on ELMG approved factors, will compute a best distribution of available assets for the TYCOMS. These "best mix" quantities will then serve as a baseline for negotiation between NAVAIR and the TYCOMS. A similar but independent manual procedure is used by the Air Force.

In summary, the Navy has established a serialized accounting and control system but has not yet developed a strong centralized management system for aircraft engines. Additionally, I perceived that the strength and direction of the Navy engine program was in the maintenance rather

than materiel management organization. This is opposite from the Air Force where the materiel management or supply side of the house has the control function. This difference is probably the result of the Navy four-echelon maintenance system.

Organization

Engine management within the Navy is more decentralized than within the Air Force. In my attempt to understand these various organizational relationships I developed Figure 11. Perusal of this figure reveals that Navy spare engine requirements computations are developed at a lower organizational level than in the Air Force. The basic disadvantage to this structure is that there are more levels of review between the individual developing the requirements and the OSD budget reviewer. This can result in a filtering of the knowledge behind the factors used in developing the requirements. Another problem of additional layering is the ability to react in a timely fashion to changes to aircraft delivery schedules that occur immediately prior to the budget submission date. Additional layering usually means additional review and therefore additional delays.

The Navy organizational structure causes a separation of the responsibilities for management and repair of whole engines and engine spare parts. This separation could cause an uneconomical imbalance in the requirements for repair of whole engines and the repair of engine spare parts. Without proper coordination and balance it is possible to have whole engines move to higher echelon maintenance facilities due to the non-availability of a spare part at the lower level maintenance facility.

This action causes the expenditure of unnecessary transportation dollars, excessive maintenance time, and misuse of scarce maintenance manhours.

ORGANIZATIONAL COMPARISON

LEVEL	AIR FORCE	NAVY	
1	AIR STAFF - Review budgets and policy.	CNO - Review budgets and policy.	
2	AFLC - Develop policy, compute spare engine requirements, and review maintenance budgets. Chair ELPB and AEL.	CNM - Review budgets and policy.	
3.	ALC - Develop requirements and accomplish repair of engines and engine spare parts. Determine requirements, procure, stoc, store, and issue engine spare parts (Inventory Control Point/ICP functions)	NAVAIR Develop policy, compute spare engine requirements, and schedule whole engine repair.	NAVSUP Determine requirements, procure, stock, store, and issue spare parts. Determine requirements and schedule repair of engine spare parts.

FIGURE 11

Requirements Methodology

The Navy implemented DODI 4230.4 through OPNAVINST 4442.3 and uses the standard DOD method for computation of spare engine procurement requirements for non-modularly designed engines. Review of the instruction and interviews with NAVAIR personnel revealed the following differences between the Air Force and Navy computations:

a. War Reserve Engines - OPNAV INST 4442.3 states "ordinarily the difference between the wartime and peacetime requirements (war reserve) will be deferred until the final production year for the applicable aircraft." The Air Force computes each fiscal year incremental quantity on the greater of the peace or war flying hour program. (6:123) Therefore, they request war reserve engine funding beginning in the second or third year of the aircraft buy and continuing until the last year of the aircraft buy. This is a major difference in ability to provide for early wartime tasking of new weapon systems.

b. Dock Stock Requirement - The Navy has been computing this offset requirement quantity when applicable and the Air Force has not been computing this segment of the requirement. Both services have been successful in getting OSD budget reviewers approval of their course of action.

c. Outfitting Requirement - This special requirement is peculiar to Navy carrier operations. It provides for an additional 30-day stock of spare engines to be on board a carrier before it sails. This requirement has been successfully defended to the OSD budget reviewer and is based on the unique operational and logistics environment pertaining to aircraft carriers.

Spare Engine and Module Requirements

The Navy recently developed NAVMET to compute spare engine and module requirements for modularly designed engines. It was developed

by the same individual who developed the Air Force's MOD-METRIC. NAVMET is another extension of RAND's METRIC model and determines the optimal quantity and distribution of spare aircraft engines and modules in a four-echelon inventory system.

Again a discussion of the mathematical basis for NAVMET is beyond the scope of both the researcher and this paper but it is covered in Dr. Muckstadt's paper "NAVMET - A Four-Echelon Model for Determining the Optimal Quantity and Distribution of Navy Spare Aircraft Engines." The model is now operational but has not yet been used to compute spare engine/module requirements for a Navy engine. NAVAIR forecasts that they will use this computation technique for FY 79 procurement requirements for engines/modules to support the F-18.

In summary a large degree of similarity exists between the Air Force and the Navy in implementation of DODI 4230.4 and in development of an alternative method for computing requirements for modular engines. The differences are, for the most part, due to the different operational and maintenance environments in the Air Force and the Navy.

SECTION IV

CONCLUSIONS

This study effort began with three goals, therefore, I will present my conclusions based on these objectives:

a. Review Air Force and Navy policy, procedures, and requirements methodology for conformance to established DOD policy and procedures - both of the services have implemented DODI 4230.4. Their implementation differs only slightly and appears to be the result of unique service requirements and differences in management philosophies. I detected a continuing effort within the Navy to attempt to bring more centralization into their management. They appear to be trying to get closer to the Air Force System.

To summarize I feel that both services have implemented DODI 4230.4 properly with only slight differences due to unique requirements.

b. Enhance the researcher's knowledge of the Navy's policy, procedures, and methodology for possible application, where appropriate, to Air Force propulsion system acquisition and management strategies. After a review of the similarities and differences in engine management I found two areas for further study. The first - the Navy SCALER system - is a revision to the existing Air Force actuarial system. It contains some changes to the structuring of historic data for making actuarial forecasts. I have provided these data to the personnel responsible for the Air Force actuarial system for evaluation. NAVMET is the second area for further study. No direct application is readily apparent because of the Air Force two-echelon maintenance system but some future application could be impossible.

c. Determine if there is a perceived need within the Air Force and Navy to recommend to OSD that the DOD Sub-Task Group on Spare Engine Requirements be re-convened to review and update DODI 4230.4. It is readily apparent from the Air Force development of NAVMET for modular engine requirements that an update of DODI 4230.4 is necessary. Therefore, I plan to develop an Air Force recommendation on this matter upon my return to Air Force Logistics Command. This project appears to be one that should be submitted to the Joint Logistics Commanders for development of a tri-service position.

In summary, the management and control of the $10.1B inventory of installed and spare engines in the Air Force and the Navy are based on similar systems. The differences are few and appear to be the result of differences in the operational and maintenance environments within the two services.

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